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ORIGINAL RESEARCH

# The Effect of Pharmacological Dilation on Calculation of Targeted and Ideal IOL Power Using Multivariable Formulas

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## ABSTRACT

***Background***: To examine the effect of pharmacologic dilation on biometric parameters measured by the Lenstar LS 900, and whether these changes affect the power of the calculated intraocular lens (IOL) using multivariable formulas in an undilated versus pharmacologically dilated state.

***Methods***: Prospective study of 98 phakic eyes from 53 patients. Axial length (AL), central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness (LT), and keratometry (K) readings were measured. The first set of measurements was taken prior to dilation. After dilation (pupil diameter $\geq$ 6.0 mm), a second set of measurements was taken. The Barrett, Olsen, Hill-RBF, Haigis, SRK/T, and Holladay I formulas were used to calculate IOL power before and after dilation. Two calculation methods were used: method A used a commonly available IOL targeted to achieve the lowest myopic spheroequivalent residual refraction; method B calculated ideal IOL power for emmetropia.

***Results***: Statistically significant increases were seen in CCT ($p < 0.01$), ACD ($p < 0.01$), and AL ($p < 0.01$) whereas a statistically significant decrease was seen in LT ($p < 0.01$) post dilation. Using method A, the percentage of eyes which would have received an IOL with 0.5 D or 1.0 D of higher power, if post-dilation measurements were used, were 25.5%, 30.6%, 20.4%, and 23.5% for Barrett, Olsen, Hill-RBF, and Haigis, respectively. Using method B, only Haigis and Olsen had a statistically significant increase in ideal IOL power.

***Conclusions***: Pharmacologic dilation can be associated with an increase in non-custom IOL dioptric power when using multivariable formulas, which may lead to a myopic surprise.

**Keywords:** Anterior chamber depth; Biometry; Dilation; IOL calculation; IOL power

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| Key Summary Points |
| --- |
| **Why carry out this study?** |
| Pharmacologic pupil dilation is associated with increased biometry measurements of anterior chamber depth (ACD). |
| Post-dilation biometry measurements may affect the power of the calculated IOL when using the Haigis formula, but not previous third-generation formulas (SRK/T, Holladay I, etc.). |
| **What was learned from the study?** |
| First study to test the effects of pharmacologic pupil dilation on the newer multivariable IOL formulas (Barrett Universal II, Olsen, Hill-RBF). |
| When using multivariable formulas, surgeons should be aware that post-dilation biometry measurements may yield a myopic surprise in a significant percentage of cases. |

## INTRODUCTION

Modern cataract surgery has become a combined restorative and refractive surgical procedure with increased patient expectations of visual function, which include minimizing the need for spectacles postoperatively. Cataract surgeons are increasingly motivated to satisfy these expectations by optimizing the accuracy of intraocular lens (IOL) calculations to improve postoperative refractive outcomes. Selection of IOL power relies on accurate preoperative biometry measurements. Third-generation IOL calculation formulas, such as Holladay I and SRK/T, rely primarily on axial length (AL) and keratometry (K) values to predict the effective lens position (ELP). It is known that there are some limitations to these older formulas, such as a decrease in IOL calculation accuracy in eyes with long and short ALs, along with decreased accuracy in the setting of low and high average K values [1, 2].

Multivariable formulas may more accurately determine IOL power by taking into account other biometric variables, such as anterior chamber depth (ACD), central corneal thickness (CCT), and lens thickness (LT), to better estimate the postsurgical ELP [3, 4]. However, some studies have demonstrated that ACD increases after pharmacological dilation, raising the question of whether dilation may influence the calculated IOL power when using these formulas [5–9]. For example, the Haigis formula, which utilizes ACD values in its calculation, has been previously shown to have statistically significant differences in computed IOL power pre- and post-dilation [7–9].

In recent years, several multivariable formulas have become increasingly popular with cataract surgeons, including the Barrett Universal II, Olsen, and Hill-RBF formulas [10]. While each of these formulas incorporates unique variables and weighs them differently, ACD is nonetheless an important variable in estimating ELP [11–14]. Given the inclusion of ACD in each of these multivariable formulas, we sought to determine if pupil dilation has an effect on calculated IOL power based on whether biometry measurements are taken in an undilated state as compared to a post-dilated state.

## METHODS

Institutional ethics approval was obtained from the Institutional Review Board at the University of Chicago (IRB17-0197) and adhered to the tenets of the Declaration of Helsinki. Informed written consent was obtained from all participants prior to enrollment, in accordance with Springer's ethical policies. The inclusion criteria for this study were the following: (1) age 18 years or older and (2) presence of lens opacity. The exclusion criteria were (1) axial length unable to be reliably measured by optical biometry; (2) anatomically narrow angle (with risk of angle closure upon dilation); (3) allergy to tropicamide or phenylephrine; (4) recent soft or rigid gas-permeable contact lens wear; (5)

history of refractive surgery; (6) faint corneal opacities; (7) keratoconus; (8) inability to perform biometry testing.

The same investigator (NCS), under supervision of an attending cataract surgeon (KMR), performed all measurements on patients using the same optical biometry device based on optical low coherence reflectometry (OLCR) [Lenstar LS 900 (Haag-Streit Diagnostics, Switzerland)]. Each subject included in the study received the first set of IOL measurements prior to pharmacological dilation. After the initial measurements, one drop each of 1% tropicamide and 2.5% phenylephrine was administered for dilation. After 30 min, pupil diameter was measured at the slit lamp to verify full dilation ($\geq$ 6 mm). If full dilation was not achieved, an additional set of dilating drops was given; the second set of measurements were taken once full dilation was achieved.

The AL, CCT, ACD, LT, and K readings, including flat K (Kf), steep K (Ks), and mean K (Km), were measured five times on each eye per standard Lenstar protocol. All biometry measurements were consistent with the validation criteria as described previously by Hill [15].

The standard deviations for the five measurements were recorded for each variable. If any standard deviation exceeded the acceptable limit, this indicated possible unreliability, and the measurements were repeated. All measurements were also taken in the same room, under the same lighting conditions, and using the same device.

A predicted refractive error for the IOL power to be implanted was calculated for the Barrett Universal II, Olsen, Hill-RBF, and Haigis formulas using the software integrated in the OLCR device's Eyesuite IOL package for a Tecnis 1 ZCB00 IOL (Johnson and Johnson Vision, Jacksonville, Florida, USA) using the parameters obtained before and after dilation.

We employed two separate prediction methods for each eye. Method A calculated IOL power available from stock increments which would yield the lowest myopic spheroequivalent residual refraction (LMP) for a targeted refraction of − 0.25 D, simulating the current scenario in our clinical practice. Method B calculated the ideal IOL power for emmetropia (IPE). Both methods have been previously described in the literature [7, 9]. Pre- and post-dilation IOL powers were compared for each eye. Similar calculations were performed for the SRK/T and Holladay I formulas as control groups. The Barrett Universal II and Hill-RBF formulas were used with the recommended constants in their online software, when available. The User Group for Laser Interference Biometry IOL constants for the OLCR device were used when calculating the Haigis, SRK/T, and Holladay I formulas [16].

## Statistical Analysis

The study used Stata version 14.1 for data analysis. $p$ values of less than 0.05 were accepted as statistically significant. A minimum sample size of 88 eyes was calculated in order to find a mean change of 0.15 mm in ACD between measurements with $\alpha = 0.05$ and $\beta = 0.20$, assuming a standard deviation of 0.25 mm in each group. ACD change was used as a proxy for IOL power in this sample size calculation (i.e., a significant detectable change in ACD was predicted to cause a significant change in IOL power).

For the biometric data, Shapiro–Wilk tests showed distributions not significantly different from normal ($p > 0.05$) for AL, CCT, ACD, and LT measurements pre- and post-dilation. Paired $t$ tests were used to compare these measurements. Shapiro–Wilk tests showed distribution significantly different from normal ($p < 0.05$) for Kf, Ks, and Km. Wilcoxon signed-rank tests were used to compare these measurements.

For the IOL power calculations, Shapiro–Wilk tests showed distribution not significantly different from normal ($p > 0.05$) for all six formulas except Barrett and Olsen post-dilation values ($p = 0.039$ and $p = 0.033$, respectively). Paired $t$ tests were used to compare each formula's IOL power calculations pre- and post-dilation and Wilcoxon signed-rank tests were used to confirm results.

In order to analyze correlated binary eye data, a mixed model was employed to account for the correlation in outcomes between paired eyes with the addition of a random effect as

**Table 1** Demographic data for studied patient population

| | |
|---|---|
| *N* | 53 |
| Age, years | |
| Mean | 65.25 |
| SD | 13.68 |
| Min | 28 |
| Max | 87 |
| Sex, *n* (%) | |
| Male | 19 (35.8) |
| Female | 34 (64.2) |
| Eye side, *n* | |
| Right | 48 |
| Left | 50 |

described in the literature [17]. For this study, a mixed model of the following form was fit: $Y_{ijt} = \alpha + u_i + b_1 t + b_2\ \text{eye}_j + b_3\ t \times \text{eye}_j + e_{ijt}$, where $Y_{ijt}$ is the measurement in the $j$th eye of the $i$th patient at time $t$ and $u_i$ is the random effect and $e_{ijt}$ is the error term. These models were fit using SAS Proc MIXED using the UN@UN correlation structure.

## RESULTS

A total of 98 eyes from 53 subjects (19 male, 34 female) were measured; 48 right eyes and 50 left eyes were analyzed. The mean age was 65.25 years. The remaining demographic data of the subjects are shown in Table 1. Several fellow eyes from these 53 subjects were excluded because of the exclusion criteria mentioned above.

The Ks, Kf, and Km measurements did not have a statistically significant change after dilation ($p = 0.10$, $p = 0.84$, $p = 0.25$, respectively) as shown in Table 2. Statistically significant increases were seen in AL ($0.0069 \pm 0.0316$, $p = 0.03$), CCT ($1.676 \pm 3.616$, $p < 0.001$), and ACD ($0.0640 \pm 0.417$, $p < 0.001$), and a statistically significant decrease was seen in LT ($-0.0397 \pm 0.1136$, $p < 0.001$).

By method A, the stock IOL with LMP for a targeted refraction of − 0.25 D was calculated. The IOL power calculated by Barrett Universal II, Olsen, Hill-RBF, and Haigis all showed statistically significant increases by calculating a higher-powered IOL based on post-dilation measurements as compared to pre-dilation measurements ($p < 0.001$) as shown in Table 3a. The IOL power calculated by the Holladay I and SRK/T formulas did not show any statistically significant differences ($p = 0.26$ and $p = 0.81$,

**Table 2** Pre-dilation and post-dilation optical low coherence biometry measurement values

| Parameters | Mean ± SD | | Mean difference ± SD | 95% CI for mean difference | *p* value |
|---|---|---|---|---|---|
| | Pre-dilation | Post-dilation | | | |
| AL (mm) | 24.17 ± 1.31 | 24.18 ± 1.31 | 0.0069 ± 0.0316 | 0.00066, 0.01307 | 0.03 |
| CCT (μm) | 538.13 ± 39.75 | 539.81 ± 40.02 | 1.676 ± 3.616 | 0.966, 2.387 | < 0.001 |
| ACD (mm) | 3.18 ± 0.360 | 3.24 ± 0.370 | 0.0640 ± 0.0417 | 0.0558, 0.0722 | < 0.001 |
| LT (mm) | 4.44 ± 0.49 | 4.40 ± 0.51 | − 0.0397 ± 0.1136 | − 0.0620, − 0.0174 | < 0.001 |
| Kf (D) | 43.15 ± 1.62 | 43.16 ± 1.62 | 0.0155 ± 0.1783 | − 0.0195, 0.051 | 0.84* |
| Ks (D) | 44.08 ± 1.66 | 44.06 ± 1.65 | − 0.0242 ± 0.2878 | − 0.0808, 0.0323 | 0.10* |
| Km (D) | 43.61 ± 1.60 | 43.60 ± 1.59 | − 0.00765 ± 0.17435 | − 0.0419, 0.0266 | 0.25* |

*$p$ value calculated by Wilcoxon signed-rank test

**Table 3** Predicted IOL power for studied formulas based on pre-dilation and post-dilation measurements for method A (lowest myopic spheroequivalent residual refraction, LMP) and actual IOL power for studied formulas based on pre-dilation and post-dilation measurements for method B (ideal power for emmetropia, IPE)

| IOL power formula | Mean ± SD | | Mean difference | 95% CI for mean difference | *p* value |
|---|---|---|---|---|---|
| | Pre-dilation | Post-dilation | | | |
| Method A | | | | | |
| Barrett Universal II | 19.68 ± 3.63 | 19.80 ± 3.64 | 0.123 ± 0.238 | 0.076, 0.169 | < 0.001** |
| Olsen | 19.65 ± 3.62 | 19.79 ± 3.61 | 0.142 ± 0.257 | 0.092, 0.193 | < 0.001** |
| Hill-RBF | 19.77 ± 3.65 | 19.86 ± 3.64 | 0.088 ± 0.238 | 0.042, 0.135 | < 0.001** |
| Haigis | 19.88 ± 3.71 | 19.99 ± 3.70 | 0.108 ± 0.250 | 0.059, 0.157 | < 0.001** |
| Holladay I | 19.80 ± 3.78 | 19.81 ± 3.77 | 0.010 ± 0.244 | − 0.038, 0.058 | 0.26 |
| SRK/T | 19.78 ± 3.65 | 19.77 ± 3.63 | − 0.010 ± 0.233 | − 0.056, 0.036 | 0.81 |
| Method B | | | | | |
| Barrett Universal II | 19.40 ± 3.58 | 19.43 ± 3.57 | 0.030 ± 0.215 | − 0.013, 0.073 | 0.16 |
| Olsen | 19.39 ± 3.54 | 19.47 ± 3.53 | 0.076 ± 0.233 | 0.030, 0.123 | 0.002 |
| Hill-RBF | 19.49 ± 3.58 | 19.52 ± 3.58 | 0.021 ± 0.216 | − 0.022, 0.064 | 0.35 |
| Haigis | 19.56 ± 3.63 | 19.61 ± 3.66 | 0.055 ± 0.259 | 0.003, 0.107 | 0.04 |
| Holladay I | 19.57 ± 3.74 | 19.57 ± 3.74 | 0.005 ± 0.213 | − 0.038, 0.047 | 0.82 |
| SRK/T | 19.44 ± 3.57 | 19.45 ± 3.57 | 0.002 ± 0.189 | − 0.035, 0.040 | 0.89 |

**$p$ value confirmed with Wilcoxon signed-rank test

respectively). Our findings suggest that, using method A, patients in our cohort with post-dilation measurements would have received an IOL with 0.5 D or 1.0 D higher power in 25.5%, 30.6%, 20.4%, and 23.5% of cases for the Barrett Universal II, Olsen, Hill-RBF, and Haigis formulas, respectively (Table 4). In contrast, by the same method, patients would have received an IOL with 0.5 D or 1.0 D lower power in only 1.0%, 2.0%, 3.1%, and 2.0% of cases for the Barrett Universal II, Olsen, Hill-RBF, and Haigis formulas, respectively.

By method B, the IPE calculated by Olsen ($p$ = 0.002) and Haigis ($p$ = 0.04) were higher on the basis of post-dilation measurements as compared to pre-dilation measurements (Table 3). However, Barrett Universal II, Hill-RBF, Holladay I, and SRK/T did not show any statistically significant differences ($p$ = 0.16, 0.35, 0.82, and 0.89, respectively).

Figure 1 shows an example of two patients, one who demonstrated changes in IOL power and one who showed no changes when using pre-dilation versus post-dilation measurements using Method A.

## DISCUSSION

Given the recent wave of interest in multivariable formulas, we sought to examine the effects of pharmacologic pupil dilation on IOL power calculated by OLCR biometry using these formulas when compared to third-generation formulas using both LMP and IPE methods (method A and method B, respectively).

We saw no significant changes in keratometry values pre-dilation versus post-dilation, which is consistent with previous biometry studies [5–9, 18]. We also observed an increased post-dilation ACD, although the increase in our

**Table 4** Pre-dilation versus post-dilation predicted IOL values

| IOL power formula | Number of eyes to receive IOL with 0.5 D or 1.0 D of lower power | Number of eyes to receive the same IOL power | Number of eyes to receive IOL with 0.5 D or 1.0 D of higher power |
|---|---|---|---|
| Barrett Universal II | 1 (1.0%) | 72 (73.5%) | 25 (25.5%) |
| Olsen | 2 (2.0%) | 66 (67.3%) | 30 (30.6%) |
| Hill-RBF | 3 (3.1%) | 75 (76.5%) | 20 (20.4%) |
| Haigis | 2 (2.0%) | 73 (74.5%) | 23 (23.5%) |
| Holladay I | 11 (11.2%) | 74 (75.5%) | 13 (13.3%) |
| SRK/T | 12 (12.2%) | 76 (77.6%) | 10 (10.2%) |

study is smaller than ACD increases reported in other studies [5–9]. Nevertheless, this increase in ACD was still large enough to cause statistically significant increases in the IOL power for the multivariable formulas used in this study.

As multivariable formulas also include variables such as LT to calculate IOL power, we observed a statistically significant decrease in post-dilation LT, confirming the recent reports of Teshigawara and colleagues [9]. Previously, Read et al. reported significant LT changes after accommodation, but other studies have failed to find changes in LT after administration of tropicamide 1% [5, 19, 20]. Therefore, it is also possible that the changes in LT after pharmacological dilation affected the multivariable formula calculated IOL power in our study. Further work is needed to confirm these recent observations.

Of note, we observed a statistically significant increase in post-dilation CCT, which is consistent with at least two other studies [18, 21]. We cannot adequately explain the physiological causes for these findings. One potential explanation is that administration of topical eyedrops may itself cause an increase in corneal epithelial thickness or smoothening of the corneal surface, leading to an increased CCT measurement [22, 23]. We also observed a small but statistically significant increase in post-dilation AL; this may be partially explained by the increase in CCT though there may be other mechanisms that affected AL as well, which are beyond the scope of this study. Notably, while an increase in AL may theoretically lead to a lower IOL power calculation, the magnitude of AL change observed in our study was not large enough to have any significant impact on IOL power calculations.

**Fig. 1** Pre-dilation and post-dilation biometry measurements for two sample patients by method A. **a** Example of a patient with 0.50-D increase in IOL power post-dilation when calculated using the Barrett, Olsen, Hill-RBF, and Haigis formulas. This patient had no change in IOL power when calculated using SRK/T and Holladay formulas. **b** Example of a patient with no changes in post-dilation IOL power calculations for all six formulas

Several studies have found no change in post-dilation calculated IOL power when using the SRK/T formula, which primarily relies on AL and K values for its calculations [5–7, 9]. Although we had a statistically significant increase in AL, the magnitude of this change was not large enough to cause a significant change in IOL power chosen. We noted similar results when performing calculations using both the SRK/T and the Holladay I formula. Therefore, though it may not be optimal clinical practice, the presence or absence of pharmacological dilation at the time of biometry will likely not significantly affect the calculated IOL power when using these third-generation formulas.

The Haigis formula was the first of the multivariable formulas to incorporate ACD as a proxy for ELP. Rodriguez-Raton et al. compared pre-dilation and post-dilation biometry results in 107 eyes and observed a significant increase (0.098, $p = 0.01$) in IOL power when using this formula that they associated with an increased ACD and subsequent posterior shifting of the ELP [7]. Khambhiphant et al. similarly found a statistically significant increase in IOL power in 373 eyes calculated by the Haigis formula after

**a**

**Example Patient 1**

**Barrett Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.50 | 0.08 |
| **20.00** | **-0.27** |
| 20.50 | -0.63 |

Selected IOL: 20.00 D

**Barrett Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.50 | 0.37 |
| 20.00 | 0.02 |
| **20.50** | **-0.33** |

Selected IOL: 20.50 D

**Olsen Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.50 | 0.18 |
| **20.00** | **-0.18** |
| 20.50 | -0.54 |

Selected IOL: 20.00 D

**Olsen Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.50 | 0.53 |
| 20.00 | 0.18 |
| **20.50** | **-0.19** |

Selected IOL 20.50 D

**Hill-RBF Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.50 | 0.12 |
| **20.00** | **-0.13** |
| 20.50 | -0.47 |

Selected IOL: 20.00 D

**Hill-RBF Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.50 | 0.38 |
| 20.00 | 0.04 |
| **20.50** | **-0.30** |

Selected IOL 20.50 D

**Haigis Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 20.00 | 0.14 |
| **20.50** | **-0.21** |
| 21.00 | -0.55 |

Selected IOL: 20.50 D

**Haigis Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 20.00 | 0.42 |
| 20.50 | 0.08 |
| **21.00** | **-0.27** |

Selected IOL 21.00 D

**Holladay Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.50 | 0.18 |
| **20.00** | **-0.15** |
| 20.50 | -0.49 |

Selected IOL: 20.00 D

**Holladay Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.50 | 0.23 |
| **20.00** | **-0.11** |
| 20.50 | -0.44 |

Selected IOL: 20.00 D

**SRK/T Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.00 | 00.15 |
| **19.50** | **-0.19** |
| 20.00 | -0.54 |

Selected IOL: 19.50 D

**SRK/T Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 19.00 | 0.20 |
| **19.50** | **-0.14** |
| 20.00 | -0.49 |

Selected IOL: 19.50 D

**b**

**Example Patient 2**

**Barrett Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.00 | 0.19 |
| **21.50** | **-0.15** |
| 22.00 | -0.51 |

Selected IOL: 21.50 D

**Barrett Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.00 | 0.22 |
| **21.50** | **-0.13** |
| 22.00 | -0.48 |

Selected IOL: 21.50 D

**Olsen Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.00 | 0.21 |
| **21.50** | **-0.14** |
| 22.00 | -0.49 |

Selected IOL: 21.50 D

**Olsen Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.00 | 0.25 |
| **21.50** | **-0.10** |
| 22.00 | -0.45 |

Selected IOL 21.50 D

**Hill-RBF Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.50 | -0.05 |
| **22.00** | **-0.38** |
| 22.50 | -0.72 |

Selected IOL: 22.00 D

**Hill-RBF Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.50 | -0.03 |
| **22.00** | **-0.36** |
| 22.50 | -0.70 |

Selected IOL 22.00 D

**Haigis Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.50 | 0.03 |
| **22.00** | **-0.31** |
| 22.50 | -0.66 |

Selected IOL: 22.00 D

**Haigis Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.50 | 0.01 |
| **22.00** | **-0.32** |
| 22.50 | -0.66 |

Selected IOL 22.00 D

**Holladay Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.50 | 0.01 |
| **22.00** | **-0.32** |
| 22.50 | -0.66 |

Selected IOL: 22.00 D

**Holladay Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.50 | 0.03 |
| **22.00** | **-0.30** |
| 22.50 | -0.64 |

Selected IOL: 22.00 D

**SRK/T Pre-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.50 | -0.04 |
| **22.00** | **-0.38** |
| 22.50 | -0.72 |

Selected IOL: 22.00 D

**SRK/T Post-Dilation**

| IOL (D) | Refraction (D) |
|---|---|
| 21.50 | -0.03 |
| **22.00** | **-0.36** |
| 22.50 | -0.70 |

Selected IOL: 22.00 D

**Fig. 1** continued

pharmacological dilation [8]. More recently, Teshigawara et al. also noted similar IOL power increases for both the Haigis and Holladay 2 formulas [9].

While we decided to analyze the potential impact of pre- versus post-dilation measurements on actual IOL powers (method A), as well as on theoretical custom IOL dioptric power (method B), we believe that method A is more relevant for cataract surgeons as it simulates clinical practice as compared to method B, which has primarily theoretical implications. In the USA, most lens manufacturers make IOLs in increments of 0.5 D.

To the best of our knowledge, this is the first study to investigate and report a difference in IOL power using two different calculation methods when performed in an undilated versus post-dilated state using the Barrett, Olsen, and Hill-RBF formulas. Our data also confirm the findings reported previously regarding IOL calculations performed in an undilated versus post-dilated state when using third-generation formulas and the Haigis formula. Our results suggest that in some patients, post-dilation biometry measurements may lead to a higher selected IOL power (when using multivariable formulas with stock IOLs), increasing the risk of myopic surprise.

It is well accepted that undilated biometry is a part of good clinical practice, for reasons such as avoiding ocular surface changes that may negatively affect measurements. Our findings further underscore additional refractive implications that may occur with post-dilation measurements, especially when using multivariable formulas. If a visually significant cataract is detected after dilation as part of the clinical exam, our findings may be used by surgeons to provide patients additional explanation as to why they may need to return for an additional visit for undilated biometry testing.

One limitation of our study is due to financial considerations we did not include the Holladay 2 formula, which also incorporates ACD and LT into its calculations. However, recent data by Teshigawara et al. found a post-dilation IOL power change with this formula as well [9]. Furthermore, postsurgical validation of mean absolute error (MAEs), median absolute errors (MedAEs), and percentage of eyes within ± 0.25, ± 0.50, and ± 1.00 D of predicted refraction would be required for our findings in order to demonstrate whether or not the predicted myopic refractive error(s) would occur postoperatively. On the basis of our preoperative findings, we could not justify using any post-dilation biometry measurements for IOL implantation and therefore cannot comment on the postsurgical refractive results at this time. Our study also did not have the required number of eyes to stratify patients on the basis of AL or keratometry values. Finally, we used database and manufacturer lens constants instead of optimized lens constants which may have led to different results had the latter been used. Future studies on this topic may be able to address these limitations.

## CONCLUSION

As the current multivariable formulas are increasing in popularity, and given the increased demands for accuracy with IOL calculations, surgeons should give increased consideration to pre-operative biometric testing in order to optimize their surgical results. Our data suggest that post-dilation biometry measurements may favor a higher-power IOL in a significant portion of cases, increasing the likelihood of a myopic surprise and a potential increase in MAEs and MedAEs. Therefore, we recommend that cataract surgery patients receive biometry testing in an undilated state, especially if multivariable IOL calculation formulas are being used.

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***Compliance with Ethics Guidelines.*** Institutional ethics approval was obtained Institutional Review Board at the University of Chicago (IRB17-0197) and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all participants prior to enrollment, in accordance with Springer's ethical policies.

***Data Availability.*** The datasets generated during and/or analyzed during the current study are not publicly available due to institutional policy regarding the displaying of research data in the public space setting. However, de-identified data are available from the corresponding author on reasonable request



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